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(71)(72) Applicant and Inventor: BARESICH, Frank, J. [US/US]; 3216 Fairview Drive, Melbourne, FL 32935 (US).

(74) Agents: SHORE, Ronald, J. et al.; Antonelli, Terry & Wands, 1919 Pennsylvania Ave., N.W., Suite 600, Washington, DC 20006 (US).

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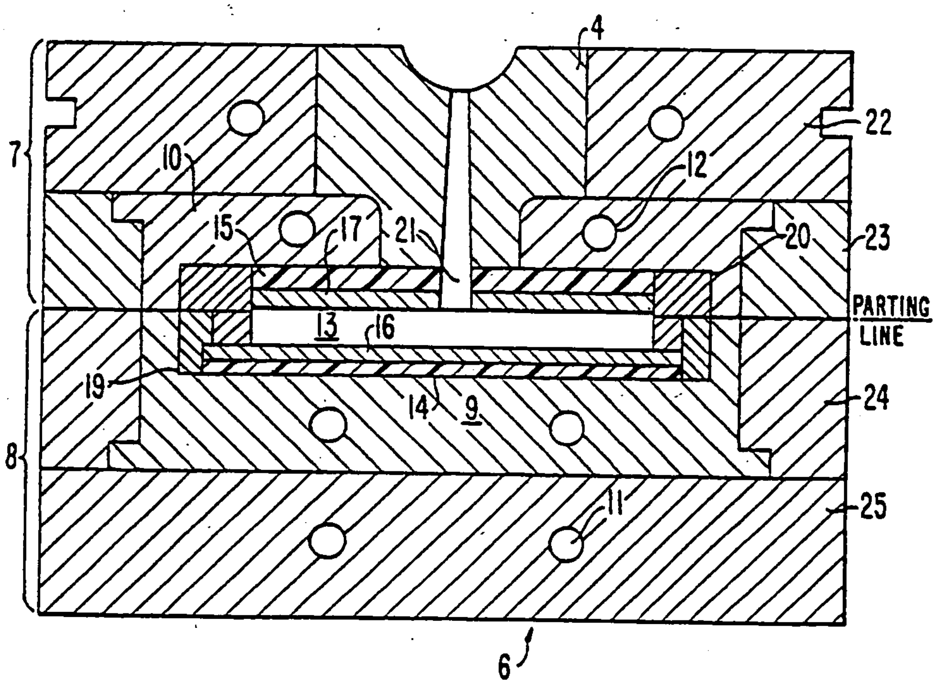
(54) Title: METHOD OF MOLDING PLASTIC AND MOLD THEREFOR



(57) Abstract

A method of molding plastic, especially injection molding or compression molding and a mold (6) therefor involves causing the surface of the mold cavity (13) to have a temperature above the solidification temperature of the molten plastic during molding of a part. The temperature of the surface of the mold cavity (13) is preferably mantained near or above the solidification temperature of the molten plastic as the center of the plastic in the mold cavity cools from a temperature above the solidification temperature toward the solidification temperature, thereby reducing flow-induced and temperature gradient-induced orientation stresses in the solidified plastic. A layer of insulation (14, 15) about the mold cavity and gate, if any, allows heat from the molten plastic to raise the temperature of the mold cavity surface to the required level.

Description

Method of Molding Plastic and Mold Therefor

Technical Field:

The present invention is directed to an improved method of molding plastic and a mold therefor. The invention is particularly adapted for injection molding plastic for molding plastic optical parts such as optical discs and lenses, or for compression molding plastic to produce phonograph records, for example.

Background Art:

In almost all molding operations pressure and heat are applied to cause a plastic to flow into the desired shape. The shape is then fixed by cooling. Thermoplastic materials must be cooled below the melting temperature or glass transition temperature before removal from the mold. Heating, flow under pressure and cooling under pressure are required in this sequence.

It is known to use an injection molding process to produce parts from amorphous or crystalline thermoplastics, for example. In this process, a hot plastic melt is forced through a small opening called a gate into the mold cavity that defines the finished part geometry. The mold is much colder than the plastic melt. Where the plastic melt initially contacts the mold surface a thin layer freezes.

In the case of amorphous plastic, regardless of the molecular orientation of the solidifying melt caused by the molten plastic flowing through the gate, the outer frozen region is relatively stress free. An intermediate layer is formed when the molecules in the melt contact the outer frozen region and freeze to it. The high flow shear stress causes these molecules to become oriented in the direction of flow. This intermediate layer is highly oriented and highly shear

rates vary significantly throughout the cavity resulting in variable skin thickness. Mechanical and physical properties of the part vary considerably depending on the distribution of skin and core thicknesses as well as the degree of orientation and crystallinity at different locations in the part.

During flow, higher pressures in the core region cause higher shear stresses and molecular orientation in the intermediate layer as the core material is pushed through. When the cavity is completely full, pressure increases rapidly. High pressure is then maintained as the part continues to cool and the thickness of the frozen layer increases. The volume of the part decreases as it solidifies and the injection pressure packs in more plastic until the gate closes or pressure is removed. After the gate closes, the part continues to cool until the frozen layer is thick and rigid enough for part ejection. The pressure decreases as the part cools and the specific volume decreases. The outer frozen layer maintains part dimensions while the core region continues to cool and shrink thus creating additional residual stresses in this known injection molding process.

Several other problems are also inherent in this known injection molding process. Parts with varying wall thicknesses will pack differently in different locations in the parts. Over packing occurs in areas of a part that fill too early and in a cavity of a family or multicavity mold that fills before the other cavities. Over packing also occurs in the area near the gate where hot plastic is forced in with the relatively cool plastic. The over packed areas are highly stressed and exhibit lower strength, warpage and part hang-up in the mold. Common methods of reducing these problems include altering part wall thicknesses,

property is directly related to the carrier-to-noise ration (CNR) and bit error rate. In particular, a magnetooptical disk using a delicate Kerr rotation angle as a signal requires a birefringence of <5 nm (double pass), and nearly 0 must be targeted.

Birefringence is calculated using the following equation (Brewster formula):

$$\delta = \frac{2\pi}{\lambda} c \; t \; (\sigma_1 - \sigma_2);$$

$$\frac{\delta\lambda}{2\pi} = c \; t \; (\sigma_1 - \sigma_2);$$

where $(\delta\gamma)/2\pi)$ = birefringence (single pass) (nm); δ = retardation (single pass); λ = wavelength of light (nm); c = photoelastic modulus (cm^2/dyn); t = thickness of a substrate (nm); and $(\sigma_1 \quad \sigma_2)$ = principal stress difference (dyn/cm^2).

The principal stress difference defined here is caused by (1) a heterogeneous residue of mold pressure and (2) and heterogeneity of mold shrinkage. In general, the higher the mold pressure and the larger the mold shrinkage, the more heterogeneous becomes the residual stress. This results in a larger principal stress difference. It is, therefore, necessary to minimize the residual stress for a minimum birefringence."

Close tolerances are difficult to achieve in crystalline plastic parts formed by the known

and that 0.625 inch is possible with special resin grades. Walls and gates freeze too quickly in heavy walled parts to allow enough plastic to enter the cavity to compensate for skrinkage. One known solution to this problem is to introduce the polymer slowly to hot molds that keep the plastic from solidifying until enough plastic is injected to compensate for shrinkage. However, such a solution is disadvantageous because it requires an additional operation before molding can begin which adds to the cost and reduces the efficiency of the molding operation.

Disclosure of the Invention:

An object of the present invention is to provide an improved method of molding plastic material to form molded parts and a mold therefor which avoid the aforementioned problems of the known plastic molding processes. More particularly, an object of the invention is to provide an improved method of injection molding and an injection mold therefor which minimize, eliminate, or otherwise control the formation of the skin layer previously described, and which reduce the temperature gradients throughout the part while it is solidifying in the mold.

A further object of the invention is to provide an improved method of injection molding and an injection mold therefor which result in minimum flow induced molecular orientation and stresses, minimum cooling induced stresses, lower injection pressure, higher quality and more consistent parts from single, family, and multicavity molds, greater control of crystallinity, minimum birefringence, stronger weld lines, more homogeneous plastic parts, better tolerance control of crystalline plastic parts, less warping of plastic parts, and void free heavy wall

the molten plastic.

A significant feature of the invention is that the heat to raise at least a substantial portion of the surface of the mold cavity to a temperature above the solidification temperature of the molten plastic during molding comes from the heat of the molten plastic forced into the mold cavity. This is accomplished in the injection mold of the invention by insulating the mold cavity by providing a layer of material that has a low thermal diffusivity at or near the mold cavity. In one form of the invention, the layer of insulating material is located beneath a layer of another material which forms the surface of the mold cavity that contacts the molten plastic during molding. In another form of the invention, the layer of insulating material itself forms at least a substantial portion of the surface of the mold cavity which contacts molten plastic during molding. The cavity surface may be coated or plated as necessary to prevent welding or other interactions between the molten plastic and the insulator. Preferably, the entire surface of the mold cavity which contacts molten plastic during molding is insulated so that its temperature is raised to a temperature above the solidification temperature of the molten plastic during molding of the plastic.

During the method of injection molding plastic material according to the invention, the temperature of the surface of the mold cavity is much colder than the solidification temperature of the molten plastic when the plastic first contacts the mold surface. This causes a layer of the plastic contacting the surface of the mold cavity to freeze. The frozen layer is remelted during the molding process when at a least substantial portion of the surface of the

being molded. The injection mold may also be formed with a plurality of mold cavities, each insulated for molding according to the injection molding method of the invention.

The method of injection molding of the invention is particularly applicable to molding plastic material to form optical parts such as an optical discs or lenses whereby the optical parts have minimum birefringence, residual stresses, and warping so that consistently high quality optical components can be made.

The method and mold of the invention also have applicability in compression molding to produce parts from plastic. In this process, the molding material is heated and placed between two heated mold halves. The mold halves are then brought together under pressure to cause the material to flow into the desired shape According to the invention, the heat from the material being molded raises the mold surface temperature above the plastic solidification temperature for an extended period. This eliminates the need to first heat and then cool the mold as in the prior art compression molding techniques. Such a compression molding technique is useful for producing high-quality phonograph records from a thermoplastic resin such as polyvinyl chloride .

These and other objects, features and advantages of the present invention will become more apparent by the following description when taken in connection with the accompanying drawings, which show, for purposes of illustration only, three embodiments in accordance with the present invention.

<u>Brief Description of the Drawings:</u>

Fig. 1 is a schematic of the filling dynamics for flow of molten plastic into a rectangular cavity

the outer surface starts to solidify with varying thicknesses of an aluminum layer about the surface of the mold cavity in mold of the invention;

Fig. 11 illustrates the mold surface temperature as a function of the time from the introduction of the molten plastic in the mold cavity for two different combinations of mold cavity lining and insulating materials in a mold according to the invention;

Fig. 12 illustrates the temperature of plastic within the mold cavity of a conventional metal mold when molding a polycarbonate plastic to form an optical disc according to a known method;

Fig. 13 shows temperature change as a function of time for center and surface of polycarbonate and for surface of metal mold of Fig. 12;

Fig. 14 is a diagram like that of Fig. 13 where the optical disk is injection molded according to the present invention.

Fig. 15 again illustrates the mold shown in fig. 6, but with the dimensions for components thereof being shown for making a double convex lens according to the invention;

Figs 16A and 16B show constant temperature lines (isotherms) in a double convex lens about the time the lens starts to solidify in an all metal mold (Fig. 16A) and in a mold according to the invention (Fig. 16B); and

Figs. 17A and 17B are like Figs. 16A and 16B except that they relate to a time when the lens is almost completely solid.

plate 23, "B" plate 24 and supporting plate 25 are typical of standard mold bases. Item 4 is a sprue bushing.

The surface layers 16 and 17 and insulator inserts 14 and 15 in the mold 6 of Fig. 4 constitute an intermediate medium between the molten plastic injected into the mold cavity 13 by way of the central gate 21, and the mold heat sink constituted by the metal inserts 9 and 10 with cooling channels 11 and 12, respectively. In the mold 18 of Fig. 5, the intermediate medium between the molten plastic and the mold heat sink is formed solely by the insulator inserts 14 and 15. Thin coatings or platings may be applied to the cavity surfaces of the insulator inserts to provide the desired hardness, wear, chemical, temperature and welding resistance to the plastic melt if necessary.

Mold 28 in Fig. 6 differs from the other two molds in that 26 and 27 are nickel metal inserts which are added to act as heat sinks in the insulator inserts 14 and 15 to increase the cooling rate at the thicker locations of the plastic part to encourage more uniform temperature throughout the part and to draw off excess heat to reduce cooling time. In all molds, the intermediate medium are selected according to the invention to have a low thermal diffusivity so that the surface of the mold cavity rapidly increases in temperature to a temperature above the solidification temperature of the molten plastic upon injection of molten plastic into the mold cavity 13. The thermal resistance of the intermediate medium is selected, so that it is high enough to allow a controlled release of heat from the molten plastic in the mold cavity to the mold heat sink so as to retard melt cool-down and to minimize melt internal

divided by the product of density and specific heat.

$$a = \frac{\kappa}{C_p \rho} \quad in^2/sec \qquad (3)$$

Note that it is also equal to the thickness squared divided by the product of thermal resistance and thermal capacitance.

$$\alpha = \frac{L2}{CR} \quad in^2/sec \qquad (4)$$

The values for thermal capacitance and resistance are determined by the thermal physical properties and geometry of the material for the intermediate medium, that is, the insulator layers or inserts 14 and 15 and the insulation members 19 and 20 and also the surface inserts or layers 16 and 17, when used, and also by designing the configuration of such material, particularly the thickness.

The effects produced by the molds 6, 18 and 28 of the invention are to cause the temperature of the surface of at least a substantial portion of the mold cavity, e.g., most and preferably the entire surface, during molding to be raised to a temperature above the solidification temperature of the molten plastic injected therein by means of the heat of the molten plastic itself. If the mold cavity is not filled too quickly, the skin on the injected plastic will be minimal to nonexistent during polymer flow and strong orientation and high shear stresses will not occur. During the earliest period of plastic contact with the surface of the mold cavity a very thin layer of plastic can solidify while the mold surface temperature is increasing. However, with the mold

inch thick and the surface layers 16 and 17, 0.062 inch thick aluminum for molding crystalline plastics such as 0.953 density 60% crystalline polyethylene plastic, Dow Chemical EP 245, with a mold cavity height or thickness of 0.125 inch with the plastic being introduced at 440°F to a 70°F mold. The solidification temperature of this plastic is 255 - 260°F.

When the molten crystalline polyethylene plastic is injected by way of the central gate 21 into the mold cavity 13, the mold surface temperature rises above the solidification temperature of the polyethylene in a fraction of a second and remains at or near the solidification temperature for about a period of 30 seconds as the temperature of the melt at the center of the mold cavity 13 cools toward the solidification temperature thereby producing a temperature gradient within the mold cavity which is less than 63°F (0.5°F x 125 mils) during solidification after the surface of the mold cavity has been raised to a temperature above the solidification temperature of the plastic.

Another insulating material which can be used to form the insulating layers or inserts 14 and 15 is a polyimide resin such as Vespel produced by Dow Chemical. The surface inserts or layers 16 and 17 can also be formed of glass instead of metal, or from some other material that provides the desired hardness, thermal capacitance and wear, chemical, temperature, and welding resistance. The surface layers 16 and 17 in the mold 6 can also be omitted as shown in mold 18 of Fig. 5. The cavities 13 in the molds 6 and 18 in Figs. 4 and 5 are thin, flat annular cavities which may, for example, be useful in forming an optical element such as an optical disc from amorphous plastic. The cavities could, of course, have other configurations such as convex for forming lenses as

thickness of the part at 12.82 seconds. Temperature gradients of 300°F exist during solidification. These results are in good agreement with the 13.9 seconds time for a complete solidification published in "Injection Molding Theory And Practice" by Ervin Rubin. Rubin's time was for 0.945 density polyethylene at 45°F injected into a 70° mold and solidifying at 266°F.

Results of the thermal analyses for molds according to the present invention using Xydar SRT-300 as the insulating (low thermal diffusivity) material and from 0 to 0.125 inch aluminum at the mold surface are shown in Fig. 8. Runs were made for 0.062 inch SRT-300 with surface aluminum thicknesses of zero, 0.032, 0.062, 0.070, 0.078, 0.100 and 0.0125 inch. As seen from Fig. 8, in all cases, the mold surface temperature rises above the solidification temperature of the polyethylene and remains near or above the solidification temperature for an extended period. The polymer can be injected at lower pressure and at a slow rate without frozen skin formation during flow. During this period, the center of the part continues to cool as shown in Fig. 9. This produces the desired low thermal gradients throughout the part as it passes through the solidification temperature at a rate that encourages crystallization. As seen in Fig. 8 and 9, the temperature gradients are less than 50°F when the surface starts to solidify after the surface of the mold and the adjacent outer surface of the plastic adjacent the mold surface have been raised to a temperature above the solidification temperature of the plastic. The zero aluminum determination places the Xydar at the surface of the polyethylene melt which may weld to it if the cavity surface is not coated or plated, the analysis being shown to determine

seconds is remelted 3.3 seconds later so that little flow-induced orientation remains. For the 0.062 inch thick aluminum surface layer, it takes only 1.3 seconds for the mold surface to exceed the solidification temperature of the plastic. For no aluminum between the Xydar insulator layers or inserts and the plastic melts, the surface of the insulator inserts forming the mold cavity are raised above the solidification temperature in less than 0.001 second.

While the above-described thermal analyses have been with respect to the use of a Xydar insulation material for the insulator inserts 14 and 15, if another insulation material is used, the thickness of the new material required to cause the same temperature and the same time period as the Xydar insulation material can be estimated from the Schmidt finite difference method equation (5) below.

DELTA TIME = L SQUARED /2 TIMES THERMAL DIFFUSIVITY (5)

where L is insulator thickness.

The relationship for Vespel insulation material thickness as compared with Xydar thickness is :

L_V squared /2 times thermal diffusivity = L_X squared /2 times thermal diffusivity

which can be expressed as $L_V = \sqrt{\dfrac{\text{Vespel diffusivity}}{\text{Xydar diffusivity}}} \times L_X$

for L_X = 0.062 inch: L_V = 0.098 inch.

Another thermal analysis of a mold according to the present invention was compared with that for a conventional metal mold for molding optical discs with polycarbonate as the amorphous plastic being molded to form an optical disc 0.047 inch thick, which is typical of optical discs. The polycarbonate has a solidification temperature of about 305°F. The results of the computer simulation for polycarbonate injected at 660°F into a metal mold having a mold cavity surface at 250°F and with a mold temperature at 200°F are shown in Fig. 12. As shown therein, a frozen skin starts to form immediately upon introduction of the molten plastic into the mold cavity. By 0.2 second after introduction, the skin is about 0.001 inch thick. Typical fill time for optical disc mold cavities is 0.2 to 0.4 sec. to minimize orientation and stresses due to flow through thick frozen layers. The gate is then shut and the part is coined or the injection pressure is profiled to reduce overpacking stresses. The outer edges and central gate areas of the parts are highly stressed due to rapid cooling. These areas do not have the low birefringence required for optical disc use which limits the area of the disc available for data storage. According to this simulation, it takes 4.6 seconds for the center of the part to cool to the solidification or glass transition temperature where it is solid. The very large temperature gradients through the part from the time the plastic first enters the mold until the center cools below the solidification temperature with this conventional injection mold and injection molding method are also evident from Figs. 12 and 13.

In contrast, according to the present invention, a 0.012 inch mold cavity surface layer of nickel in the injection mold was backed up by an insulating layer

mold with surface temperature of 240°F, and for polycarbonate at 575°F injected into a 180°F mold 28, Fig. 6, with a surface temperature of 240°F. For efficiency of analysis, symmetry was taken into account and only one quarter of the cross-sectional area and a 0.008 radian pie slice thickness was modeled.

The results of the analysis are shown in Figs. 16A, 16B and 17A and 17B. These figures show lines of constant temperature (isotherms) in the plastic lens at specific times after injection of the plastic. Figure 16A shows the plastic in the all metal mold (known method) and the results with the method and mold according to the present invention are depicted in Fig. 16B about the time that a portion of the lenses start to solidify. The maximum temperature difference in the plastic in the known method is about 295°F with very steep temperature gradients at the surface as evidenced by the closeness of the lines which are 37.8°F apart. The maximum temperature difference in the plastic in the improved method of the invention is only 165°F and the temperature gradients are much more gradual as seen by the relatively even spacing between lines which are 18.6°F apart.

Figures 17A and 17B show the plastic lens at about the time that it has completely solidified in the case of each mold. The maximum temperature difference in the lens in the all metal mold is 110°F. For the mold according to the invention, the maximum temperature difference in the lens is 63°F. The temperature gradients are less steep in the improved method of the invention as shown by the closeness of isotherms which are 13°F apart in the all metal mold and 7.8°F apart in the mold according to the invention.

that the same is not limited thereto, but is susceptible to numerous changes and modifications as known to those skilled in the art. For example, it is envisioned that the method of the invention is applicable to injection molding other plastics than those specifically referred to herein and that the injection mold of the invention can also have other forms than those illustrated herein. In particular, the method and mold of the invention could be used for compression molding plastic in which case the gate in the mold would not be necessary as a slug of plastic would be placed between mold halves and then compressed therein. Therefore, I do not wish to be limited to the details shown and described herein, but intend to cover all such changes and modifications as are encompassed by the scope of the amended claims.

4. A method according to claim 1, further comprising insulating the mold cavity so that the heat to cause at least a substantial portion of the surface of the mold cavity to have a temperature above the solidification temperature of the molten plastic during molding comes from the heat of the molten plastic introduced into the mold cavity.

5. A method according to claim 4, wherein said step of insulating the mold cavity comprises providing a layer of material having a low thermal diffusivity at or near the surface of the mold cavity.

6. A method according to claim 5, including providing a layer of insulating material at or near the entire surface of said mold cavity that contacts molten plastic during said molding.

7. A method according to claim 5, wherein said layer of insulating material forms at least a substantial portion of the surface of the mold cavity.

8. A method according to claim 5, wherein said layer of insulating material is located beneath a layer or layers of other materials which form the surface of the mold cavity and also act as a heat sink to draw off excess heat to minimize cooling time and to cause more even temperature throughout the part during molding.

9. A method according to claim 1, wherein said mold includes a gate or gates through which molten plastic is injected into said mold cavity during molding.

to be molded, at least one gate in said mold through which molten plastic can be forced into said mold cavity, and means for causing at least a substantial portion of the surface of the mold cavity to have a temperature above the solidification temperature of the molten plastic injected into said mold cavity during molding.

16. An injection mold according to claim 15, wherein said means for causing at least a substantial portion of the surface of the mold cavity to have a temperature above the solidification temperature of the molten plastic maintains the temperature of the at least substantial portion of the surface of the mold cavity near or above the solidification temperature of the molten plastic for an extended period of time during molding while the mold cavity is filled with molten plastic and while the center of molten plastic in the mold cavity cools from a temperature above the solidification temperature toward the solidification temperature whereby flow-induced and temperature gradient induced stresses in a solidified mold material of the molded part are minimized or avoided.

17. An injection mold according to claim 15, wherein said means for causing a temperature above the solidification temperature comprises insulation provided above the mold cavity.

18. An injection mold according to claim 17, wherein said insulation is in the form of a layer of material having a low thermal diffusivity located at or near the surface of the mold cavity.

wherein said insulation is also provided about the gate of said mold.

26. An injection mold according to claim 15, wherein said means for causing a temperature above the solidification temperature causes the entire surface of the mold cavity to have a temperature above the solidification temperature of the molten plastic during molding.

27. An injection mold according to claim 15, wherein said mold cavity is configured for forming an optical part such as a lens or optical disc as the molded part.

28. An injection mold according to claim 15, wherein said means defining at least one mold cavity defines a plurality of mold cavities.

29. A method of injection molding plastic to form molded parts, comprising the steps of providing a mold defining at least one mold cavity in the form of a part to be molded, said mold including heat sink means spaced from said mold cavity and an intermediate medium located between the mold cavity and said heat sink means and means for injecting molten plastic into said mold cavity, said intermediate means having a low thermal diffusivity and appropriate thickness such that the surface of the mold cavity rapidly increases in temperature to a temperature above the solidification temperature of the molten plastic after injection of the molten plastic into the mold cavity, and said intermediate medium having a thermal resistance high enough to allow a controlled release of heat from the molten plastic in the mold cavity to the heat sink

FIG. 1

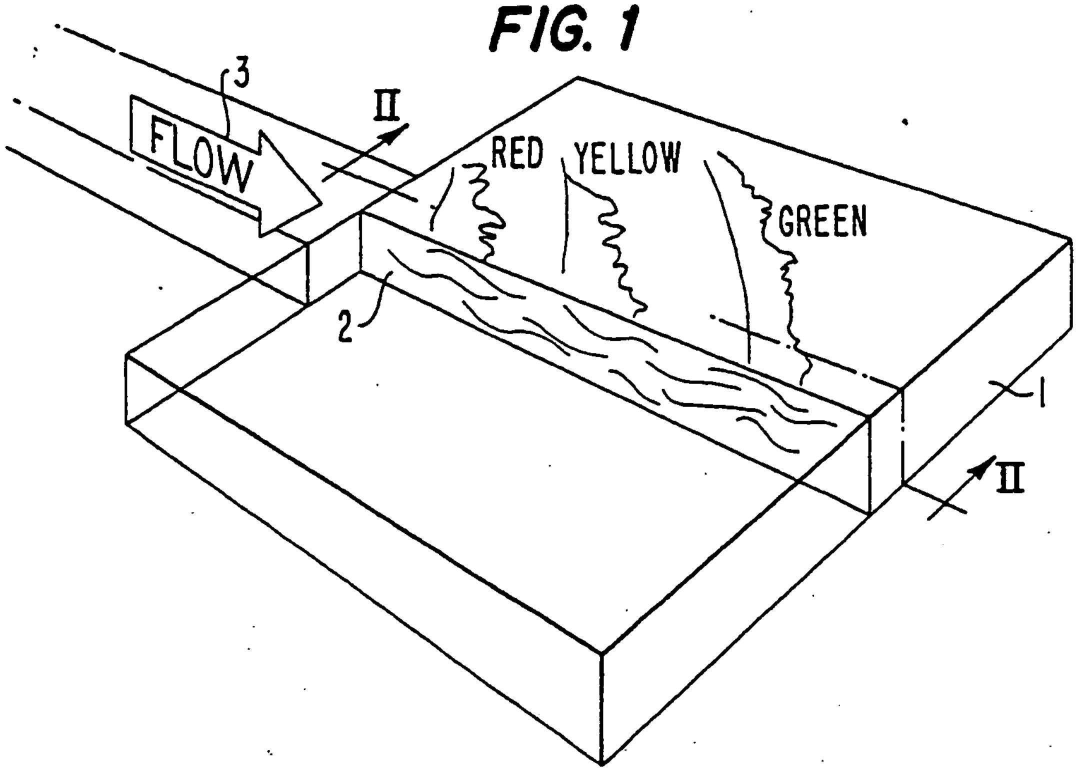
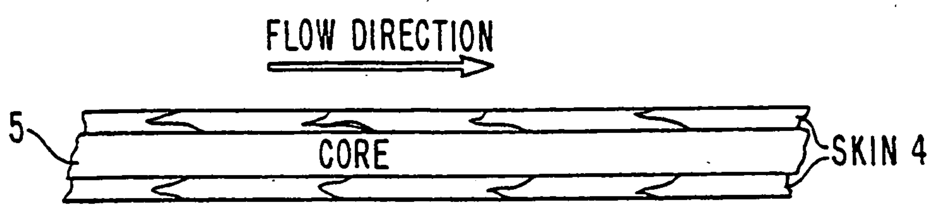
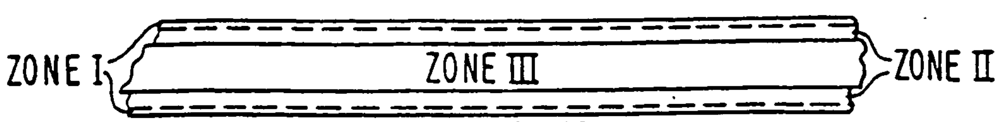


FIG. 2



HYDRODYNAMIC SKIN-CORE STRUCTURE

FIG. 3



MORPHOLOGIC ZONES

FIG. 6

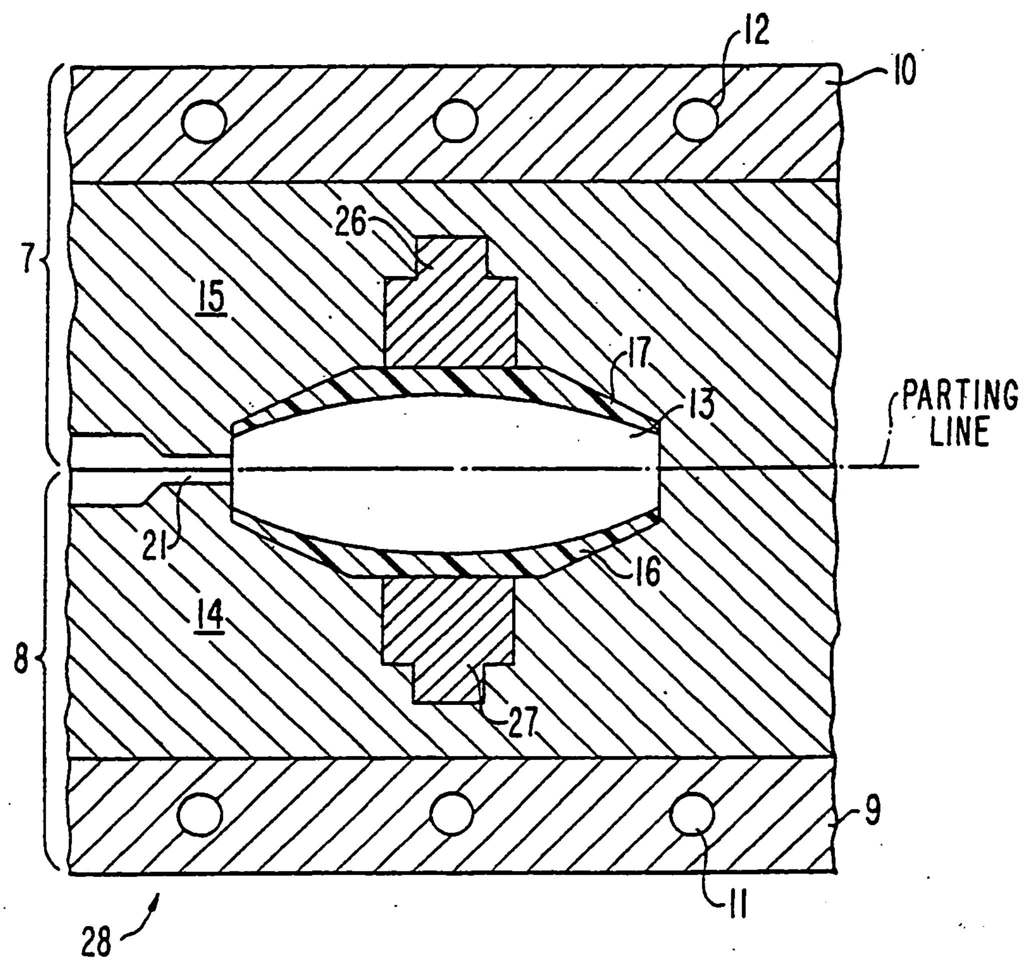
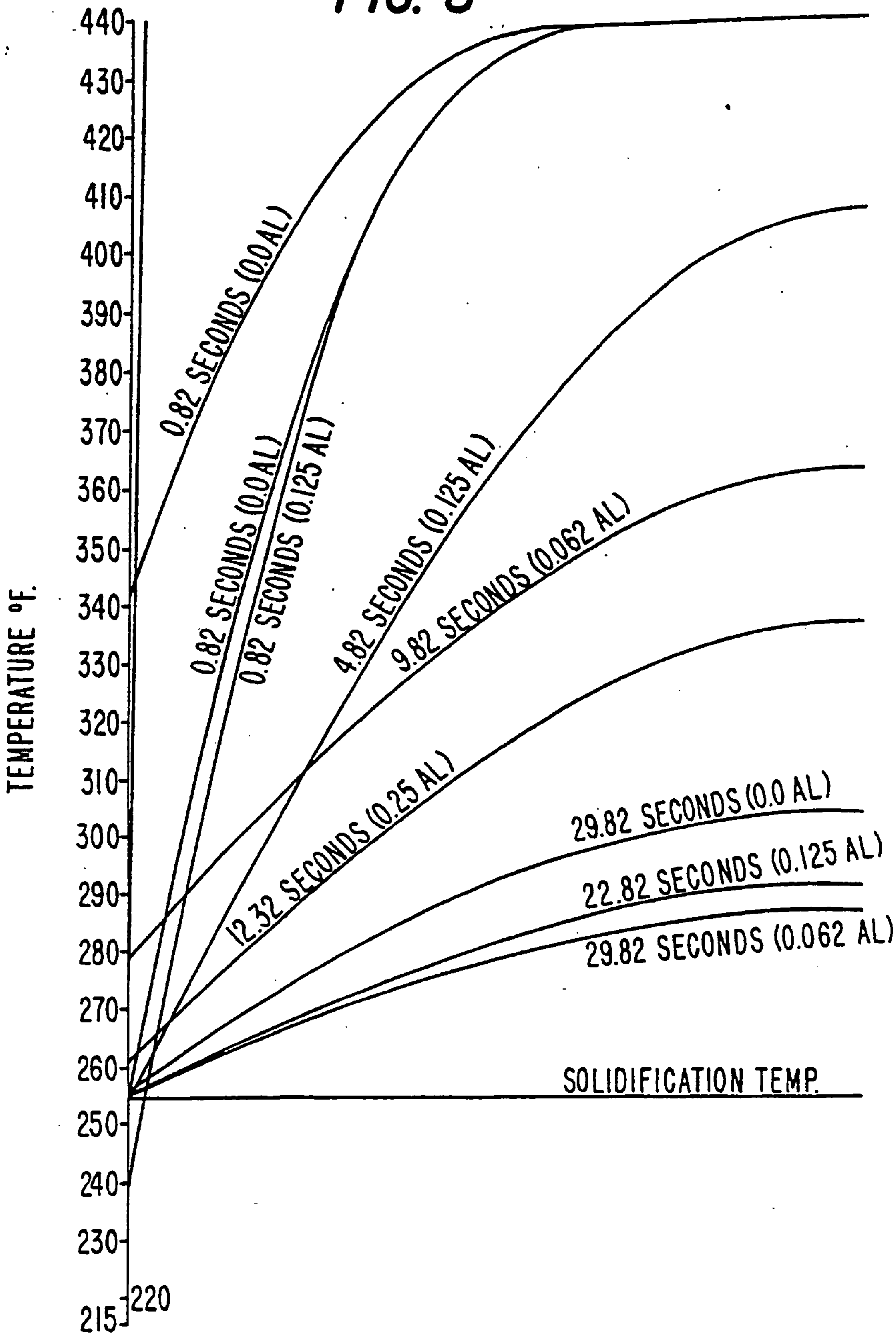


FIG. 8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400
390
380
370
360
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340
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320
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300
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280
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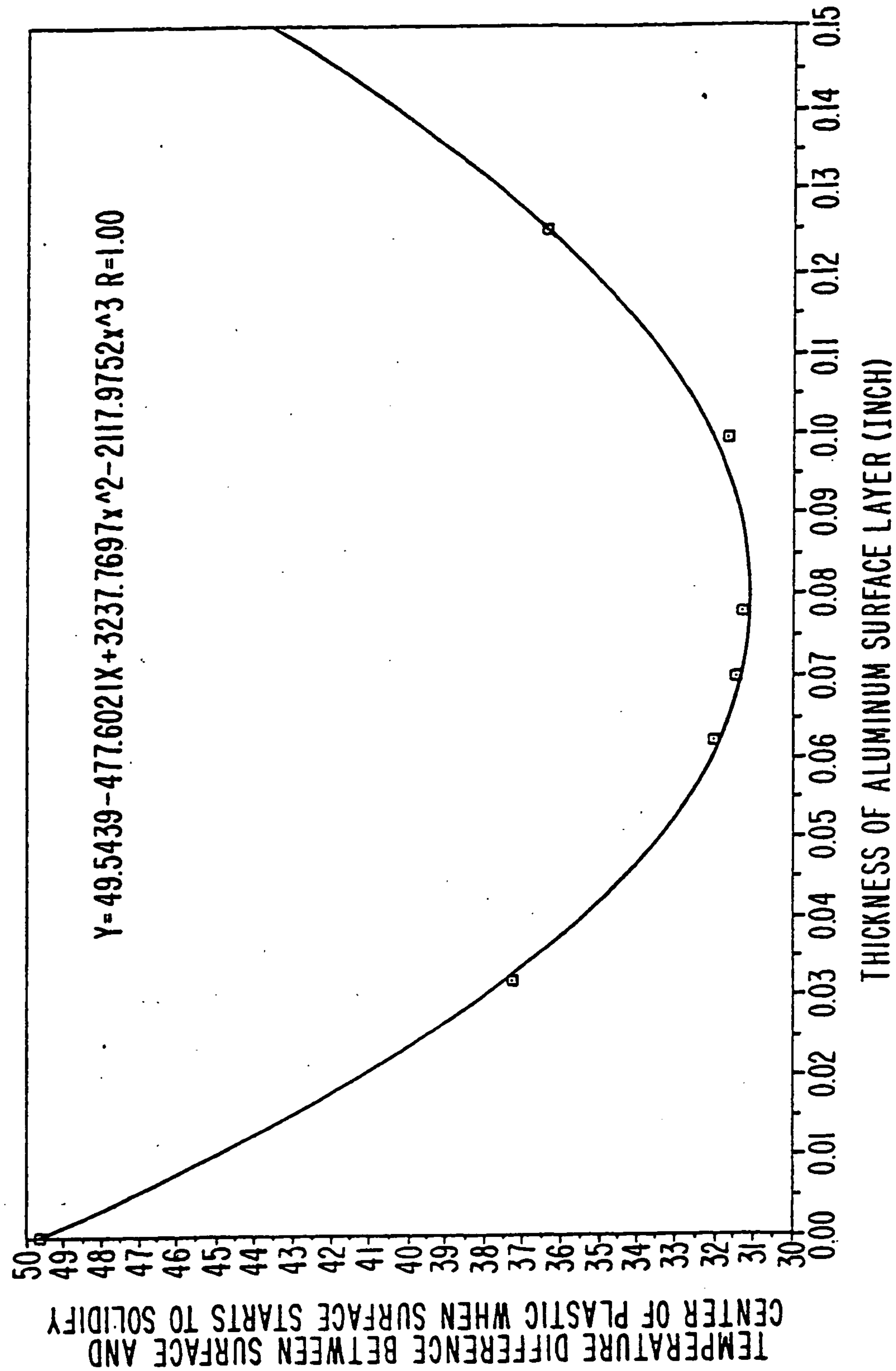
260
250
240
230
220
215
TEMPERATURE °F.
0.82 SECONDS (0.0 AL)
0.82 SECONDS (0.0 AL)
0.82 SECONDS (0.125 AL)
4.82 SECONDS (0.125 AL)
9.82 SECONDS (0.062 AL)
12.32 SECONDS (0.25 AL)
29.82 SECONDS (0.0 AL)
22.82 SECONDS (0.125 AL)
29.82 SECONDS (0.062 AL)
SOLIDIFICATION TEMP.

FIG. 10


Y=49.5439-477.6021X+3237.7697x^2-2117.9752x^3 R=1.00
THICKNESS OF ALUMINUM SURFACE LAYER (INCH)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
0.11
0.12
0.13
0.14
0.15
TEMPERATURE DIFFERENCE BETWEEN SURFACE AND CENTER OF PLASTIC WHEN SURFACE STARTS TO SOLIDIFY
30
31
32
33
34
35
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37
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39
40
41
42
43
44
45
46
47
48
49
50

FIG. 12

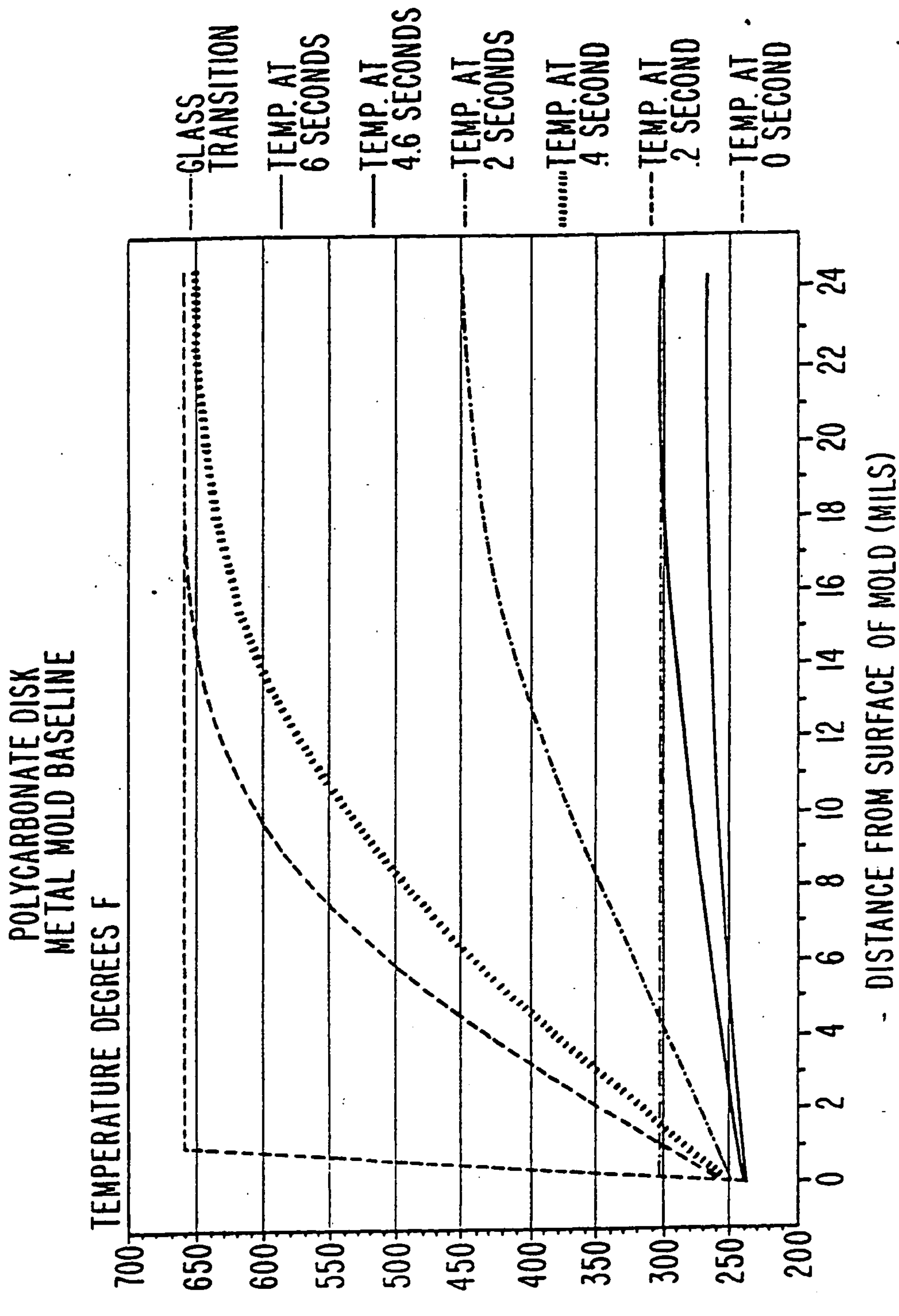

POLYCARBONATE DISK
METAL MOLD BASELINE
TEMPERATURE DEGREES F
700
650
600
550
500
450
400
350
300
250
200
0
2
4
6
8
10
12
14
16
18
20
22
24
DISTANCE FROM SURFACE OF MOLD (MILS)
GLASS TRANSITION
TEMP. AT 6 SECONDS
TEMP. AT 4.6 SECONDS
TEMP. AT 2 SECONDS
TEMP. AT .4 SECOND
TEMP. AT .2 SECOND
TEMP. AT 0 SECOND

FIG. 14

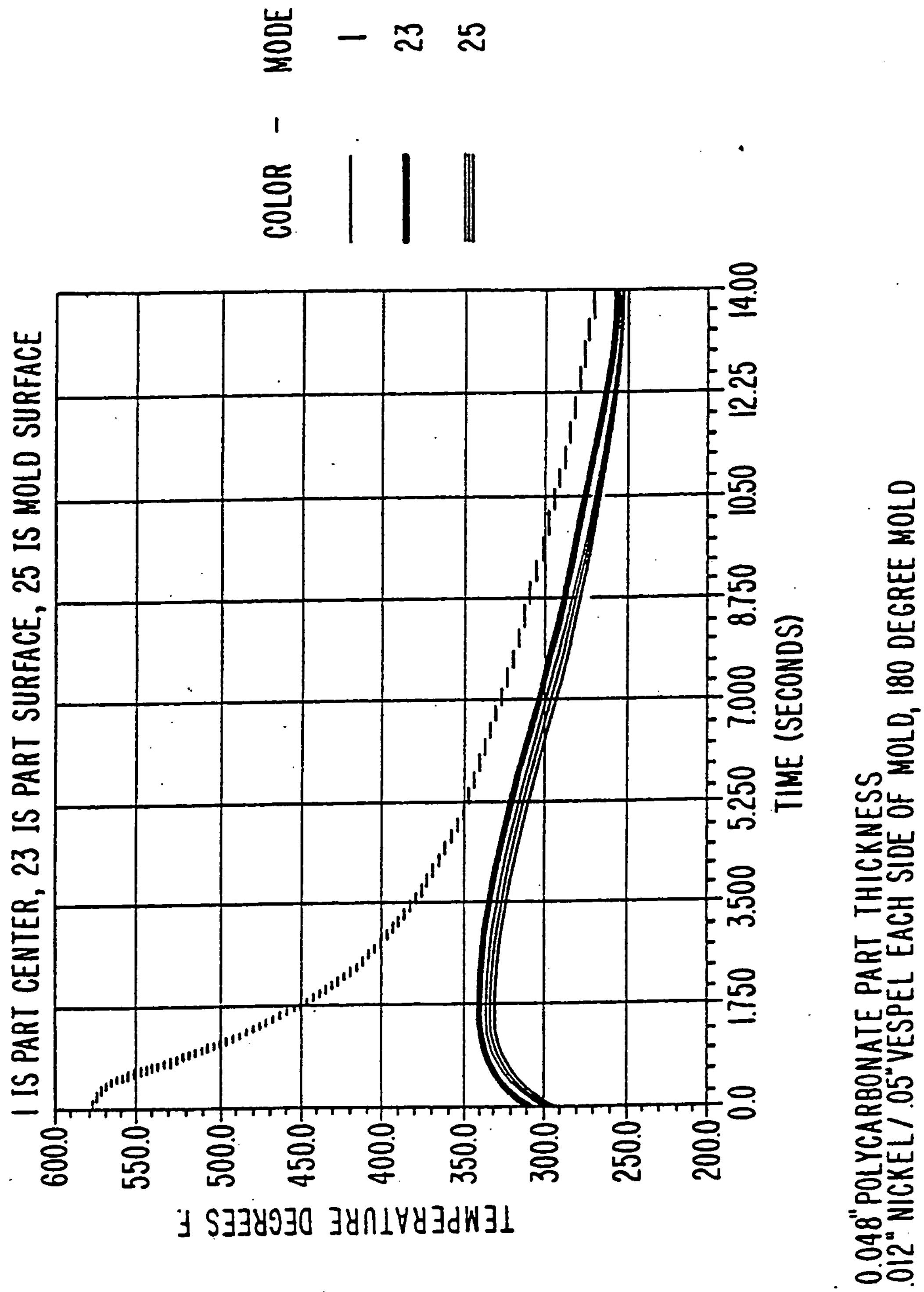
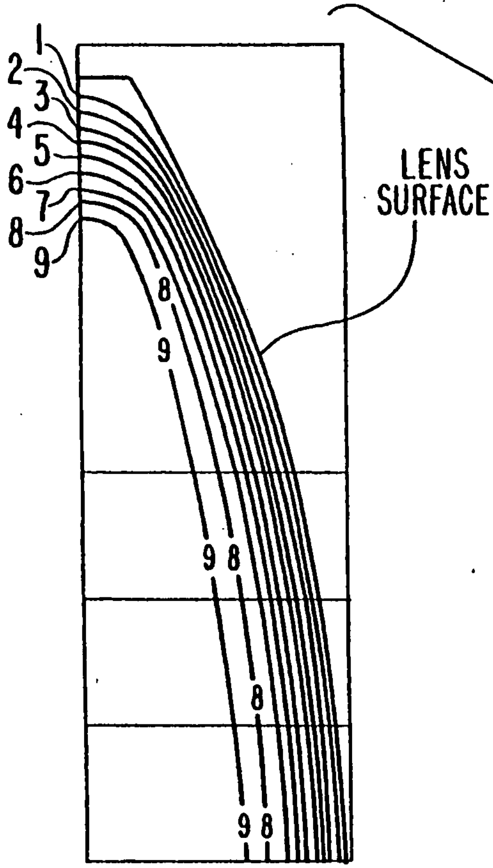

1 IS PART CENTER, 23 IS PART SURFACE, 25 IS MOLD SURFACE
COLOR - MODE
1
23
25
TEMPERATURE DEGREES F
600.0
550.0
500.0
450.0
400.0
350.0
300.0
250.0
200.0
0.0
1.750
3.500
5.250
7.000
8.750
10.50
12.25
14.00
TIME (SECONDS)
0.048" POLYCARBONATE PART THICKNESS
.012" NICKEL / .05" VESPEL EACH SIDE OF MOLD, 180 DEGREE MOLD

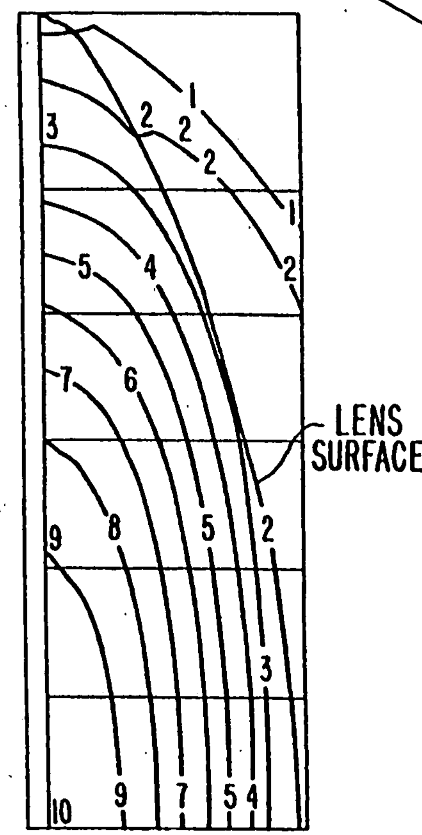
FIG. 16A



MAX	600.5
9	563.7
8	531.3
7	494.0
6	456.2
5	418.4
4	380.6
3	342.8
2	305.0
MIN	267.2

DOUBLE CONVEX POLYCARBONATE LENS
ALL METAL MOLD (5 SECONDS)

FIG. 16B



MAX	472.1
9	453.6
8	435.0
7	416.4
6	397.9
5	379.3
4	360.7
3	342.1
2	323.6
MIN	305.0

DOUBLE CONVEX POLYCARBONATE LENS, QUARTZ MOLD
SURFACE, NICKEL TAILORING HEAT SINK,
XYDAR INSULATOR (55 SECONDS)

INTERNATIONAL SEARCH REPORT

International Application No PCT/US89/01907

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(3): B29C 45/02; B29C 45/73; B29D 11/00

U.S.CL.: 249/80, 114.1; 264/327, 328.16

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
U.S.	249/78, 79, 80, 105, 111, 112, 114.1, 115, 116, 134, 135 264/327, 328.14, 328.16; 425/808

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
Y	US, A, 2,253,697 (GENESY) 26 August 1941, SEE THE ENTIRE DOCUMENT	12, 27
Y	US, A, 3,734,449 (ITOU ET AL) 22 May 1973, SEE COLUMN 2, LINES 47-66	20, 21
X	US, A, 4,285,901 (YOTSUTSUJI ET AL) 25 August 1981, SEE COLUMN 1, LINES 50-59 and COLUMN 4, LINES 48-63	1-11,15-19, 24-26,29-31
X	US, A, 4,338,068 (SUH ET AL) 6 July 1982, SEE ENTIRE DOCUMENT	1,2,15,16
A,P	US, A, 4,605,524 (DANKER) 12 August 1988, SEE ENTIRE DOCUMENT	
Y,P	US, A, 4,783,041 (SAKAIDA ET AL) 8 November 1988, SEE ENTIRE DOCUMENT	12, 27
A	EP, A, 0,122,207 (LANDRY) 17 October 1984, SEE THE ENTIRE DOCUMENT	
A	EP, A, 0,202,372 (KRAL) 26 November 1986, SEE THE ENTIRE DOCUMENT	

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search

31 July 1989

Date of Mailing of this International Search Report

24 AUG 1989

International Searching Authority

ISA/US

Signature of Authorized Officer

Allan R. Kuhns

ALLAN R. KUHNS